L. Scotian Shelf-Georges Bank-Gulf of Maine Pollock by R.K. Mayo and L. Col

1.0 Background

Pollock, *Pollachius virens* (L.) Are assessed as a unit stock from the eastern Scotian Shelf (NAFO Division 4V) to Georges Bank, the Gulf of Maine and portions of the Mid-Atlantic region (Subareas 5 and 6). This stock was last assessed over its range via VPA at SAW 16 in 1993 (Mayo and Figuerido 1993, NEFSC 1993a, 1993b). At that time, spawning stock biomass had been declining since the mid-1980s, and was expected to reach its long-term average (144,000 mt). Fishing mortality was estimated to be 0.72 in 1992, above $F_{20\%}$ (0.65) and well above Fmed (0.47). The stock was then considered to be fully exploited and at a medium biomass level.

The state of this stock was most recently evaluated in 2000 via index assessment (Mayo 2001). At that time, it was noted that biomass indices for the Gulf of Maine-Georges Bank portion of the stock, derived from NEFSC autumn bottom trawl surveys, had increased during the mid-1970s, declined sharply during the 1980s, but have been generally increasing since the mid-1990s. Indices derived from Canadian bottom trawl surveys, conducted on the Scotian Shelf, increased during the 1980s, but declined sharply during the early 1990s. The index assessment provided no basis with which to evaluate the state of the stock relative to the control rule as determined by the Overfishing Definition Review Panel (Anon. 1998).

An assessment of this stock over the major portion of its range (NAFO Divisions 4VWX and Subdivision 5Zc) has been conducted by Canada since 1989. The most recent full stock assessment was conducted in 1999 (Neilson et al. 1999) and the most recent update was performed in 2001. In 1999, it was noted that age 5+ population biomass reached a maximum in 1985 and then declined steadily to a minimum in 1995. Biomass had increased slightly after 1995 due to recruitment from the 1992 year class. Recent recruitment has been declining, and it was concluded that most indicators of stock status suggest that the resource remains depleted. The 2001 update indicated a further decline in the relative biomass indices and a reduction in the size structure of the population.

2.0 The Fishery

2.1 Divisions 4VWX and Subareas 5&6

Nominal commercial catches from the Scotian Shelf, Gulf of Maine, and Georges Bank region increased from an annual average of 38,200 mt during 1972-76 to 68,800 mt in 1986 (Table L1, Figure L1). Canadian landings increased steadily from 24,700 mt in 1977 to an annual average of 43,900 mt during 1985-87, while U.S. landings increased from an average of 9,700 mt during 1973-77 to more than 19,000 mt annually from 1985-1987, peaking at 24,500 mt in 1986. Landings by distant-water fleets declined from an annual average of 9,800 mt during 1970-73 to less than 1,100 mt per year during 1981-88. Distant-water fleet landings increased to 3,300 mt in 1991, but have since declined to negligible levels. Over time, most of the distant water fleet catch has been taken by the USSR/Russian fleet on the Scotian Shelf (Table L1).

By 1996, USA and Canadian landings had declined to 2,963 mt and 9,145 mt, respectively, the lowest landings by either country in over 3 decades. Landings by distant water fleets fishing on the Scotian Shelf remained almost negligible. Since 1996, USA and Canadian landings have increased slightly but remain low relative to past levels. From 1999 to 2001, USA landings fluctuated between 4,111 and 4,600 mt, and Canadian landings ranged from 5,700 to 7,700 mt (Table L1).

Since 1984, the USA fishery has been restricted to areas of the Gulf of Maine and Georges Bank west of the line delimiting the USA and Canadian fishery zones. The Canadian fishery occurs primarily on the Scotian Shelf and additional landings are obtained from Georges Bank east of the line delimiting the USA and Canadian fishery zones. This fishery on the Scotian Shelf has shifted westward over time, and the contribution to the total catch from larger, mobile gear vessels has steadily diminished since 1981.

2.2 Subareas 5&6

The commercial fishery in Subareas 5&6 is dominated by United States landings with additional catches taken by some distant water fleets primarily during the 1970s and by Canada. The total landings increased steadily from less than 10,000 mt during the 1960s to a maximum of over 26,000 mt in 1986 (Figure L2). Landings declined sharply during the late 1980s and have remained below 10,000 mt throughout most of the 1990s. Landings since 1999 have fluctuated between 5,000 and 6,000 mt.

3.0 Research Survey Indices

Indices of relative biomass (ln re-transformed), derived from NEFSC autumn bottom trawl surveys have varied considerably since 1963 (Table L2, Figure L2). Indices generally fluctuated between 2 and 5 kg per tow throughout most of the 1960s and 1970s, peaking at over 5-7 kg per tow during the mid-to-late 1970s, reflecting recruitment of several moderate-to strong year classes from the early 1970s. Strong year classes were also produced in 1979 and 1980, after which recruitment began to diminish.

Biomass indices declined rapidly during the early 1980s, and continued to decline steadily through the early 1990s, remaining below 1 kg per tow and reaching a minimum in 1994. Since 1994, biomass indices from the Gulf of Maine-Georges Bank region have generally increased, reaching 1.5 kg per tow in 1999 and 2.45 kg/tow in 2001 (Table L2, Figure L2). On the Scotian Shelf, Canadian biomass indices, derived from commercial fishery catch rates, declined rapidly after 1985, following the recruitment of the 1979 year class. After increasing slightly from 1994 to 1996, catch rate indices have continued to decline (Neilson et al. 1999).

4.0 Assessment Results

4.1 Divisions 4VWX and Subareas 5&6

As evident from recent trends in total landings from the entire stock and NEFSC autumn biomass indices calculated for the Gulf of Maine-Georges Bank region, exploitation ratios (total landings/NEFSC autumn biomass index) peaked in the mid-to-late 1980s after which they steadily declined (Table L3, Figure L3). Biomass indices from the Gulf of Maine-Georges Bank region have been increasing since the late 1990s, and now indicate that biomass may have returned to levels evident during the early 1980s. Measures of stock biomass on the Scotian Shelf, however, remain extremely low relative to past levels.

4.2 Subareas 5&6

As evident from recent trends in total landings from Subareas 5 and 6 and NEFSC autumn biomass indices calculated for the Gulf of Maine-Georges Bank region, exploitation ratios (Subarea 5&6 landings/NEFSC autumn biomass index) peaked in the mid-to-late 1980s after which they steadily declined (Table L3, Figure L4). Biomass indices from the Gulf of Maine-Georges Bank region have been increasing during the late 1990s and now indicate that biomass may have returned to levels evident during the early 1980s.

Relative Exploitation Rate Analyses

An index of relative exploitation (catch/survey biomass index) corresponding to a replacement ratio of 1.0, as described in NEFSC (2002) was developed for the portion of the unit stock of pollock within the USA EEZ (NAFO Subareas 5&6). Autumn NEFSC survey biomass indices from the Gulf of Maine and Georges Bank region from 1963 through 2001 (Figure L5) were used to calculate the replacement ratios, defined as the biomass index in the current year divided by the average biomass indices from the previous 5 years. The biomass indices and total landings (Figure L6) from the same region were used to compute the relative exploitation rates, defined as the catch in the current year divided by the 3 year average survey biomass index for the current year and the previous 2 years (Figure L7). These relative exploitation rates (or relative F) may be considered a proxy for F for that portion of the pollock stock considered in this analysis.

Prior to the 1980s, a high proportion of the replacement ratios equaled or exceeded 1.0 (Figure L8). During the 1980s and early 1990s, most of the replacement ratios were less than 1.0, with ratios greater than 1.0 appearing again by the late 1990s as the biomass indices began to gradually increase from the very low levels of the mid-1990s.

The relationship between replacement ratios and relative F was evaluated by a linear regression of the Log_e replacement ratio on Log_e relative F (NEFSC 2002) and the results were used to derive an estimate of relative F corresponding to a replacement ratio of 1.0 (Figure L9). Results for pollock were highly significant (NEFSC 2002), and the estimate of the relative replacement F (F rel rep) has a low standard error compared to the point estimate (5.88). The regression

indicates that, on average, when the relative F is greater than 5.88, the stock is not likely to replace itself in the long-term.

The data displayed in Figures L5, L8 and L10 also provide a means to derive a biomass index which relates to the replacement ratios. In this case, it is evident that most of the replacement ratios below 1.0 occurred during the 1980s when the biomass index was less than about 3.0. This index may be considered as the biomass proxy for Bmsy that corresponds to the relative F proxy for Fmsy.

5.0 Biological Reference Points

Since the relative F relates the catch directly to survey biomass, the catch corresponding to the Bmsy proxy can be estimated from the relative F and the biomass index of Bmsy. For pollock, this computes to 3.0 * 5.88 = 17.64, or 17,640 mt as a proxy for MSY.

The following biological reference point proxies were obtained from an index-based model of replacement ratios (NEFSC 2002) derived from indices of relative exploitation (Table L3):

MSY	17,640 mt
B_{MSY}	3.00 kg/tow
F_{MSY}	5.88 (Relative F)

Since the mid-1990s, the NEFSC autumn survey biomass has been increasing towards the 3.0 kg/tow Bmsy proxy, and the replacement ratio has remained at or above 1.0. Since 1999 the relative F has remained below the 5.88 Fmsy proxy.

Short term projections indicate total commercial landings (including Canadian) of 5,500 mt from Subareas 5&6 in 2003 based on a relative F which will allow the biomass to increase by 10% annually.

6.0 Sensitivity Analysis

Clearly, analyses that are directly linked to survey indices will be more sensitive to changes in survey catchability than model-based analyses such as VPA. The sensitivity of estimates of relative F and replacement ratios to presumed changes in survey catchability during autumn 2000 and 2001 were evaluated and the results are presented in Section 4.2. Results are summarized in Section 5.2 (Summary of Assessment Advice).

7.0 Summary

In 2001, the 3-year average biomass index for pollock was 1.60, approximately 58% of the 3.00 Bmsy proxy. Thus, current biomass is estimated to be between ½ Bmsy and Bmsy. In 2001, the 3-year average relative F was 3.55, approximately 60% of the 5.88 Fmsy proxy. Thus, current F is estimated to be below Fmsy. Accordingly, in 2001 the stock was not overfished and overfishing was not occurring.

8.0 GARM Panel Comments

After the survey proxy reference point analyses were described, the GARM panel suggested that performance of the method should be verified by comparing results from the proxy method with estimates of absolute values of the same reference points derived from VPA-based results.

The projections of catch based on a 10% growth in biomass should be updated in the present analysis using 2001 starting conditions.

The survey biomass indices which form the basis of the estimates of the biomass and F proxy reference points are based on a set of survey strata that have been incompletely sampled over the 1963-2001 time period. The Panel recommends that the survey data be re-evaluated with a goal of achieving a consistent strata set over the entire time period.

9.0 Sources of Uncertainty

- Survey indices for pollock exhibit considerable inter-annual variability
- Movement of pollock among the NAFO Divisions comprising the stock unit is likely to vary over time, contributing to the year effects noted in the surveys

10.0 References

Anon. 1998. Evaluation of existing overfishing definitions and recommendations for new overfishing definitions to comply with the Sustainable Fisheries Act. Final Report. Overfishing Definition Review Panel. June 17, 1998.

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Mayo, R.K. 2001. Pollock. In: Assessment of 19 Northeast Groundfish Stocks through 2000. Northern and Southern Demersal Working Groups, Northeast Regional Stock Assessment Workshop. NMFS, Northeast Fisheries Science Center Reference Document 01-20, 217p.

NEFSC 1993a. Report of the 16th Northeast Regional Stock Assessment Workshop (16th SAW). Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. NMFS, Northeast Fisheries Science Center Reference Document 93-18, 118 p.

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Table L1. Pollock landings (metric tons, live) from Divisions 4VWX and Subareas 5 and 6 by country, 1960-2001.

Year	Canada	USA	FRG	GDR	Japan	Spain	USSR	Cuba	Others	Total DWF	Total
1960	29470	10132	0	0	0	783	0	0	1	784	40386
1961	26323	10265	0	0	0	982	0	0	1	983	37571
1962	31721	7391	0	0	0	0	0	0	0	0	39112
1963	28999	6650	126	0	0	0	793	0	28	947	36596
1964	30007	6006	208	0	0	0	4603	0	429	5240	41253
1965	27316	5303	71	0	0	1361	2667	0	11	4110	36729
1966	18271	3791	0	0	0	2384	9865	0	12	12261	34323
1967	17567	3312	0	0	0	1779	644	0	15	2438	23317
1968	18062	3276	0	0	0	1128	372	0	7	1507	22845
1969	15968	3943	1188	2195	0	1515	227	0	7	5132	25043
1970	10753	3976	3233	4710	40	532	527	0	0	9042	23771
1971	11757	4890	633	6849	15	912	2216	0	3	10628	27275
1972	18022	5729	475	4816	8	616	3495	0	58	9468	33219
1973	26990	6303	1124	948	1570	3113	3092	0	36	9883	43176
1974	24975	8726	149	2	40	1500	2301	0	62	4054	37755
1975	26548	9318	236	95	0	708	2004	0	124	3167	39033
1976	23568	10863	994	24	0	303	1466	0	390	3177	37608
1977	24654	13056	368	0	1	2	182	0	53	606	38316
1978	26801	17714	0	0	110	0	502	141	39	792	45307
1979	29967	15541	7	0	19	0	1025	50	23	1124	46632
1980	35986	18280	0	0	81	0	950	32	99	1162	55428
1981	40270	18171	0	0	15	0	358	0	90	463	58904
1982	38029	14357	0	0	3	0	297	84	44	428	52814
1983	32749	13967	0	0	6	0	226	261	22	515	47231
1984	33465	17903	0	1	1	0	97	123	46	268	51636
1985	43300	19457	0	0	17	0	336	66	77	496	63253
1986	42845	24542	0	0	51	0	564	387	81	1083	68470
1987	45407	20353	0	0	82	0	314	343	28	767	66527
1988	41690	14960	0	0	1	0	1054	225	0	1280	57930
1989	41093	10553	0	0	1	0	1782	99	478	2360	54006
1990	36178	9645	0	0	0	0	1040	261	3	1304	47127
1991	37931	7950	0	0	38	0	1117	459	167	1781	47662
1992	32002	7183	0	0	72	0	1006	1015	9	2102	41287
1993	20253	5629	0	0	0	0	176	644	0	820	26702
1994	15240	3768	0	0	0	0	0	10	0	10	19018
1995	9781	3358	0	0	0	0	0	58	0	58	13197
1996	9145	2963	0	0	0	0	6	129	0	135	12243
1997	11927	4267	0	0	0	0	0	64	0	64	16258
1998	14371	5583	0	0	0	0	1	9	0	10	19964
1999	7737	4594	0	0	0	0	0	6	0	6	12337
2000	5676	4043	0	0	0	0	0	0	0	0	9719
2001	6306	4111	0	0	0	0	0	0	0	0	10417

1996-1999 Canadian Data Preliminary
1994-2001 USA Data Preliminary
1999 DWF Data Preliminary

Table L2. Stratified mean catch per tow in numbers and weight (kg) for Scotian Shelf, Gulf of Maine, and Georges Bank pollock in **NEFSC offshore spring[1], summer[2], and autumn[1] bottom trawl surveys**, 1963-2001.

	Spring[3]				Summer				Autumn			
	Weight		Numbers		Weight		Numbers		Weight		Numbers	
Year	Linear	Retrans-formed	Linear	Retrans-formed	Linear	Retrans-formed	Linear	Retrans-formed	Linear	Retrans-formed	Linear	Retrans-formed
1963	-	-	-	-	10.28	3.45	2.31	1.07	5.79	4.96	1.46	1.32
1964	-	-	-	-	5.27	2.32	2.06	0.96	4.35	2.42	1.63	1.04
1965	-	-	-	-	2.56	1.05	1.72	0.63	2.75	2.12	0.83	0.77
1966	-	-	-	-	-	-	-	-	2.35	1.61	0.97	0.58
1967	-	-	-	-	-	-	-	-	1.80	1.16	0.52	0.44
1968	4.50	2.90	1.10	0.93	-	-	-	-	3.17	2.30	0.69	0.62
1969	2.66	2.53	1.12	0.99	1.75	1.19	0.70	0.47	6.59	3.01	1.31	0.85
1970	4.91	3.53	1.67	1.47	-	-	-	-	2.59	2.00	0.64	0.62
1971	4.39	3.30	1.18	1.05	-	-	-	-	3.96	1.90	1.09	0.69
1972	5.67	4.07	4.43	2.62	-	-	-	-	4.37	3.13	1.41	1.16
1973	4.82	3.77	4.00	1.61	-	-	-	-	4.71	4.04	1.64	1.25
1974	4.10	4.43	1.39	1.24	-	-	-	-	3.18	1.52	0.90	0.56
1975	5.90	5.37	1.67	1.32	-	-	-	-	2.04	1.50	0.70	0.50
1976	6.84	7.02	1.59	1.48	-	-	-	-	16.66	7.32	3.69	1.70
1977	3.38	3.04	1.61	1.23	9.98	8.35	2.07	1.67	8.78	5.26	2.14	1.25
1978	6.56	3.71	2.48	1.06	4.05	3.80	1.29	0.92	5.83	3.56	0.98	0.67
1979	4.75	4.07	1.06	0.97	17.57	4.14	2.96	1.19	5.81	4.67	1.28	0.91
1980	4.40	3.92	1.52	1.17	9.83	6.61	12.21	2.25	4.63	3.32	0.83	0.68
1981	6.17	5.42	1.95	1.40	-	-	-	-	7.75	1.56	5.24	0.63
1982	6.62	3.68	3.98	2.02	-	-	-	-	3.14	1.63	1.40	0.78
1983	1.83	1.20	0.90	0.69	-	-	-	-	3.03	1.41	0.98	0.61
1984	2.87	2.06	1.00	0.84	-	-	-	-	1.10	0.70	0.43	0.38
1985	26.81	7.85	13.70	3.05	-	-	-	-	2.43	1.97	1.12	0.77
1986	7.69	4.10	1.84	1.25	-	-	-	-	1.83	1.20	0.88	0.58
1987	13.17	2.50	6.94	1.14	-	-	-	-	2.01	1.20	0.60	0.51
1988	1.98	1.36	0.89	0.74	-	-	-	-	12.83	1.75	3.71	0.86
1989	5.17	2.18	1.98	1.02	-	-	-	-	1.20	0.61	1.86	0.76
1990	1.79	1.14	0.75	0.55	-	-	-	-	2.11	1.05	0.83	0.60
1991	5.14	2.96	2.32	1.44	-	-	-	-	1.04	0.64	0.72	0.54
1992	3.35	2.17	1.79	1.24	-	-	-	-	1.69	0.92	1.05	0.65
1993	1.63	1.29	1.64	1.16	-	-	-	-	0.76	0.56	1.03	0.56
1994	1.17	0.94	0.59	0.54	-	-	-	-	0.72	0.41	0.50	0.37
1995	3.89	1.48	3.46	0.89	-	-	-	-	1.38	0.67	0.93	0.54
1996	1.07	0.75	0.65	0.51	-	-	-	-	1.10	0.70	1.02	0.69
1997	4.51	2.01	3.33	1.78	-	-	-	-	1.49	0.98	1.74	0.90
1998	2.69	1.65	2.64	1.56	-	-	-	-	1.29	0.76	2.07	0.74
1999	1.07	0.86	2.16	1.02	-	-	-	-	3.07	1.52	2.40	1.40
2000	1.35	0.98	1.49	0.98	-	-	-	-	1.42	0.83	2.74	1.33
2001	2.03	1.28	1.69	1.27	-	-	-	-	3.57	2.45	2.38	1.81

[1] Strata 13-40 (See Figure 3).
[2] Strata 21-28 and 37-40 (See Figure 3).
[3] The "36 Yankee" trawl was used from 1968-1972, and 1982-1999; the "41 Yankee" trawl was used from 1973-1981. No gear conversion factors are available to adjust for differences in fishing power.

Table L3. Total commercial landings (mt), NEFSC autumn survey biomass index (kg/tow,Ln, retransformed), replacement index and exploitation ratio for pollock in NAFO Subareas 5&6.

Year	Total Landings (mt)	NEFSC Autumn Survey Biomass Index (kg/tow) Annual	3-yr Avg	Relative F Ratio Annual	3-yr Avg	Replacement Ratio 5-yr Avg
1963	6241	4.960		1.258		
1964	9008	2.420		3.722		
1965	9000	2.120	3.167	4.245	2.842	
1966	9847	1.610	2.050	6.116	4.803	
1967	8534	1.160	1.630	7.357	5.236	
1968	5222	2.300	1.690	2.270	3.090	0.937
1969	9822	3.010	2.157	3.263	4.554	1.566
1970	11976	2.000	2.437	5.988	4.915	0.980
1971	15203	1.900	2.303	8.002	6.600	0.942
1972	13013	3.130	2.343	4.158	5.553	1.509
1973	13076	4.040	3.023	3.237	4.325	1.637
1974	12393	1.520	2.897	8.153	4.278	0.540
1975	13871	1.500	2.353	9.247	5.894	0.596
1976	13382	7.320	3.447	1.828	3.883	3.027
1977	16273	5.260	4.693	3.094	3.467	1.502
1978	22305	3.560	5.380	6.265	4.146	0.906
1979	18452	4.670	4.497	3.951	4.103	1.219
1980	23539	3.320	3.850	7.090	6.114	0.744
1981	22068	1.560	3.183	14.146	6.932	0.323
1982	19466	1.629	2.170	11.950	8.972	0.443
1983	17816	1.414	1.534	12.600	11.612	0.480
1984	20633	0.700	1.248	29.476	16.537	0.278
1985	21069	1.967	1.360	10.711	15.488	1.141
1986	26507	1.205	1.291	21.998	20.537	0.829
1987	22347	1.202	1.458	18.592	15.327	0.869
1988	17304	1.753	1.387	9.871	12.479	1.351
1989	11903	0.608	1.188	19.577	10.022	0.445
1990	11201	1.054	1.138	10.627	9.840	0.782
1991	9600	0.640	0.767	15.000	12.511	0.550
1992	10225	0.920	0.871	11.114	11.735	0.875
1993	9873	0.496	0.685	19.905	14.406	0.498
1994	7099	0.409	0.608	17.357	11.670	0.550
1995	4362	0.667	0.524	6.540	8.324	0.948
1996	4164	0.704	0.593	5.915	7.018	1.124
1997	5483	0.984	0.785	5.572	6.985	1.539
1998	7441	0.758	0.815	9.817	9.126	1.163
1999	5591	1.522	1.088	3.673	5.139	2.161
2000	5240	0.833	1.038	6.291	5.050	0.899
2001	5680	2.448	1.601	2.320	3.548	2.549

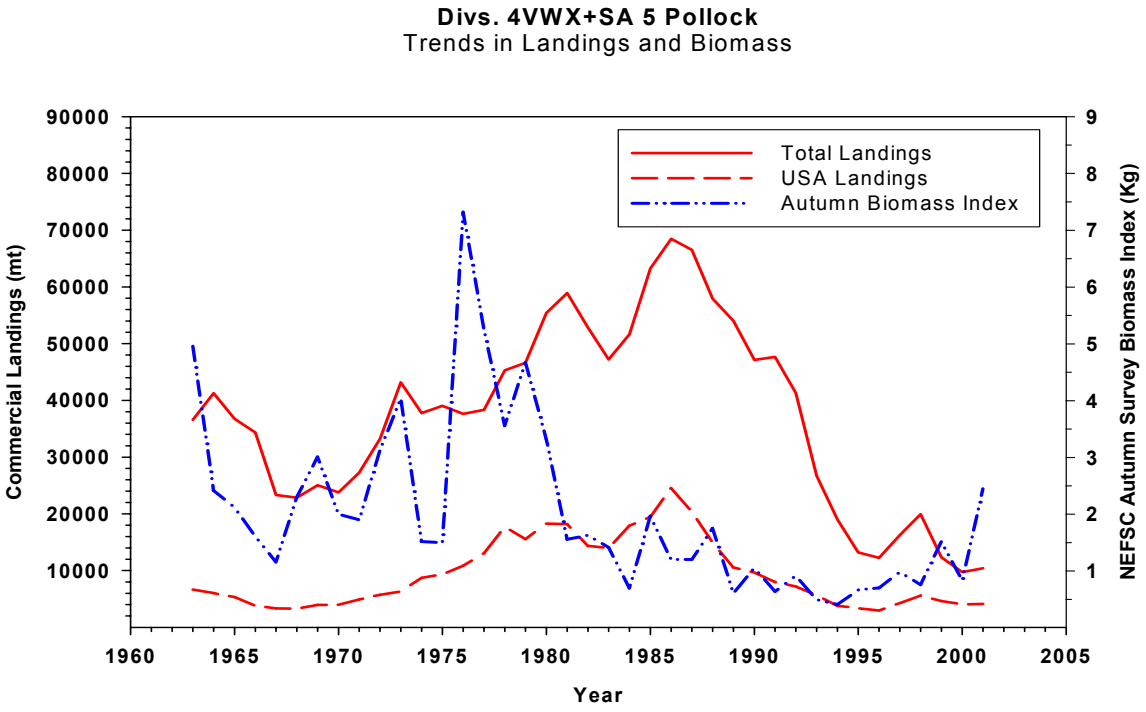

Figure L1. Trends in total and USA landings of pollock from Divisions 4VWX and Subareas 5 and 6, and NEFSC autumn survey biomass index (kg/tow), 1963-2001.

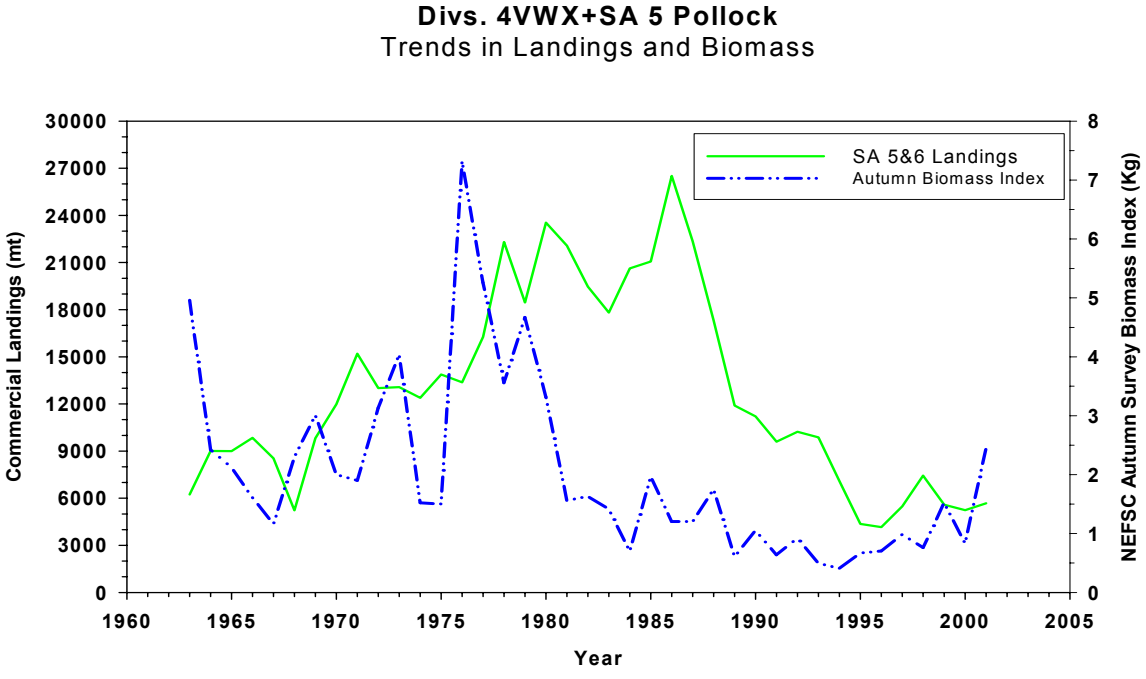

Figure L2. Trends in total landings of pollock from Divisions 4VWX and from Subareas 5 and 6, and NEFSC autumn survey biomass index (kg/tow), 1963-2001.

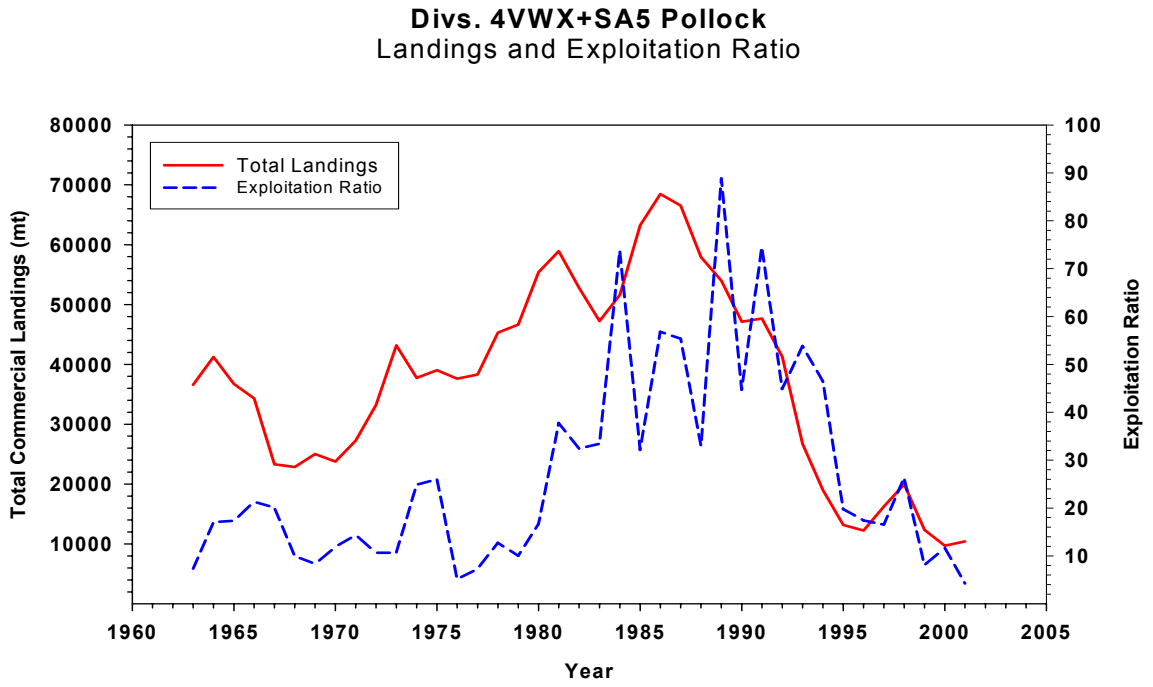

Figure L3. Trends in total landings of pollock from Divisions 4VWX and Subareas 5 and 6, and indices of relative exploitation (landings/survey biomass), 1963-2001.

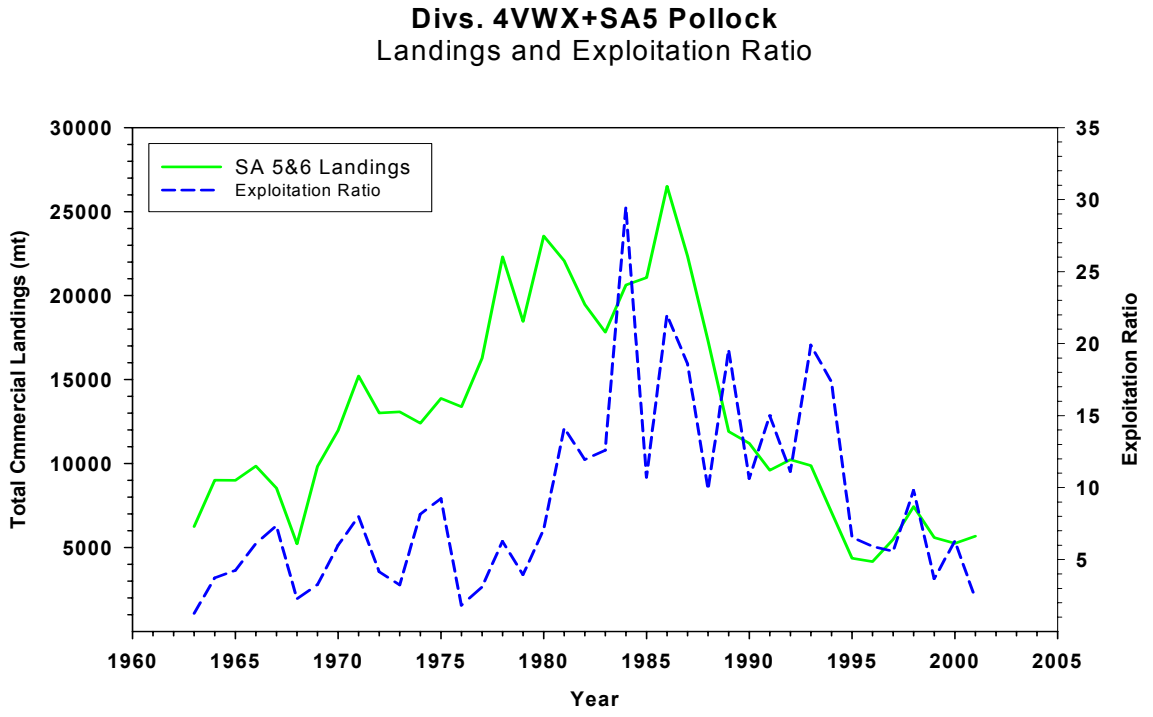

Figure L4. Trends in total landings of pollock from Subareas 5 and 6, and indices of relative exploitation (landings/survey biomass), 1963-2001.

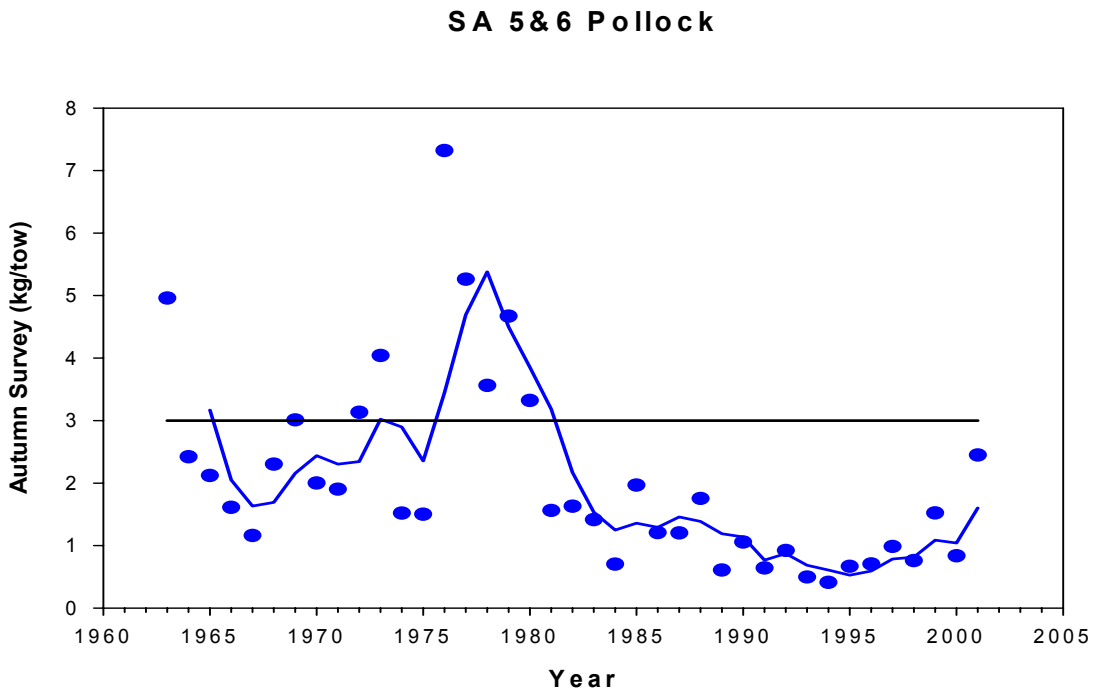

Figure L5. Trends in the NEFSC autumn survey biomass index for pollock from Subareas 5 and 6, 1963-2001.

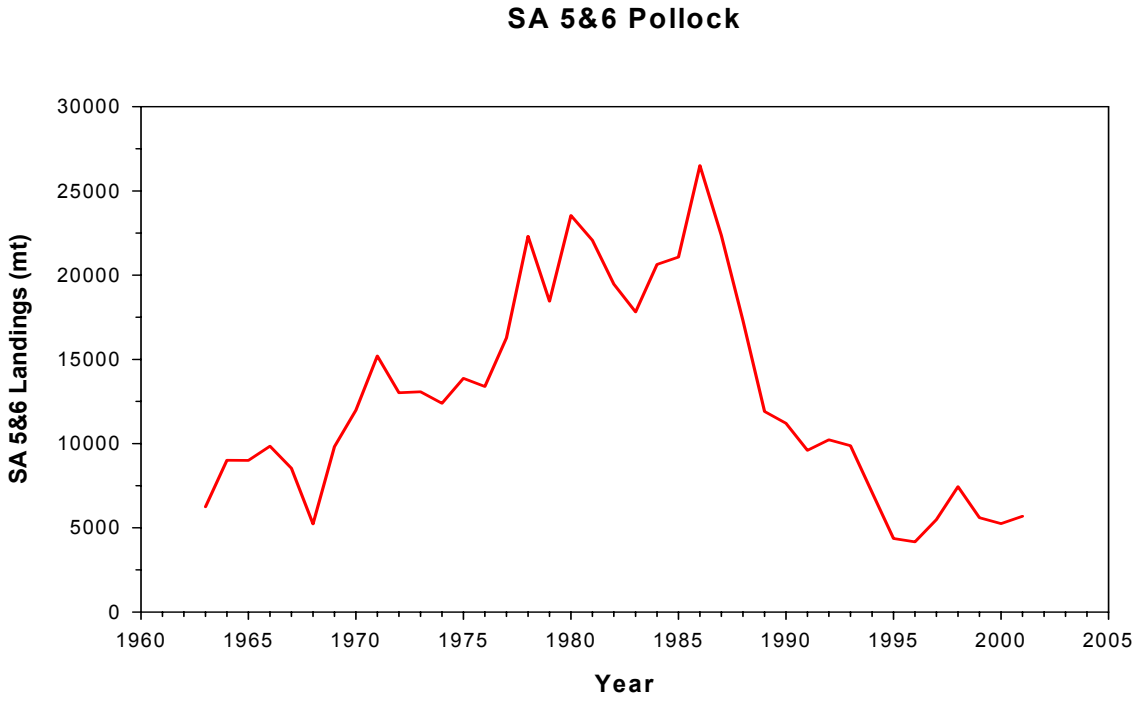

Figure L6. Trends in total landings of pollock from Subareas 5 and 6, 1963-2001.

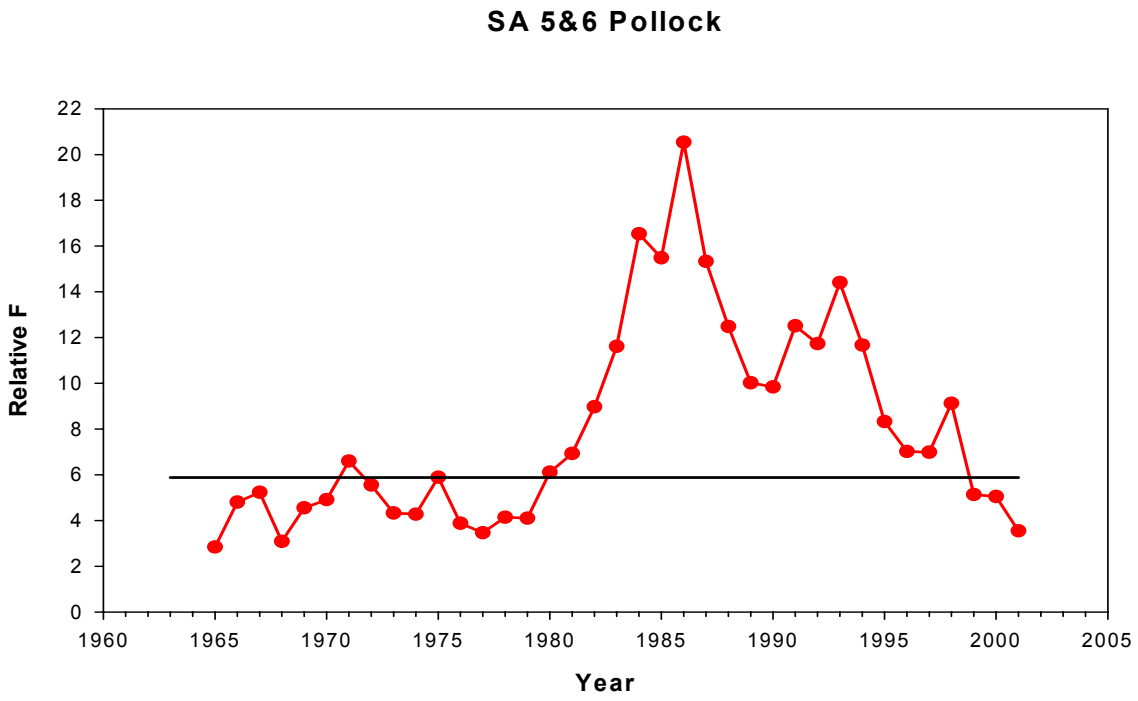

Figure L7. Trends in relative F for pollock in Subareas 5 and 6, 1963-2001.

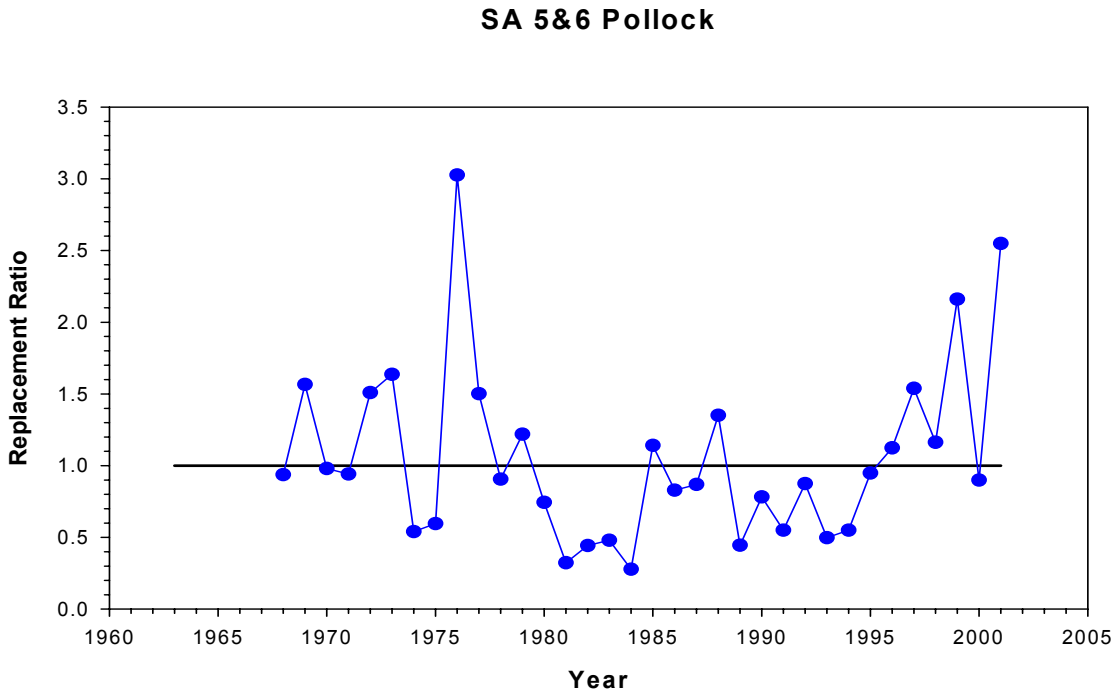

Figure L8. Trends in replacement ratio for pollock in Subareas 5 and 6, 1963-2001.

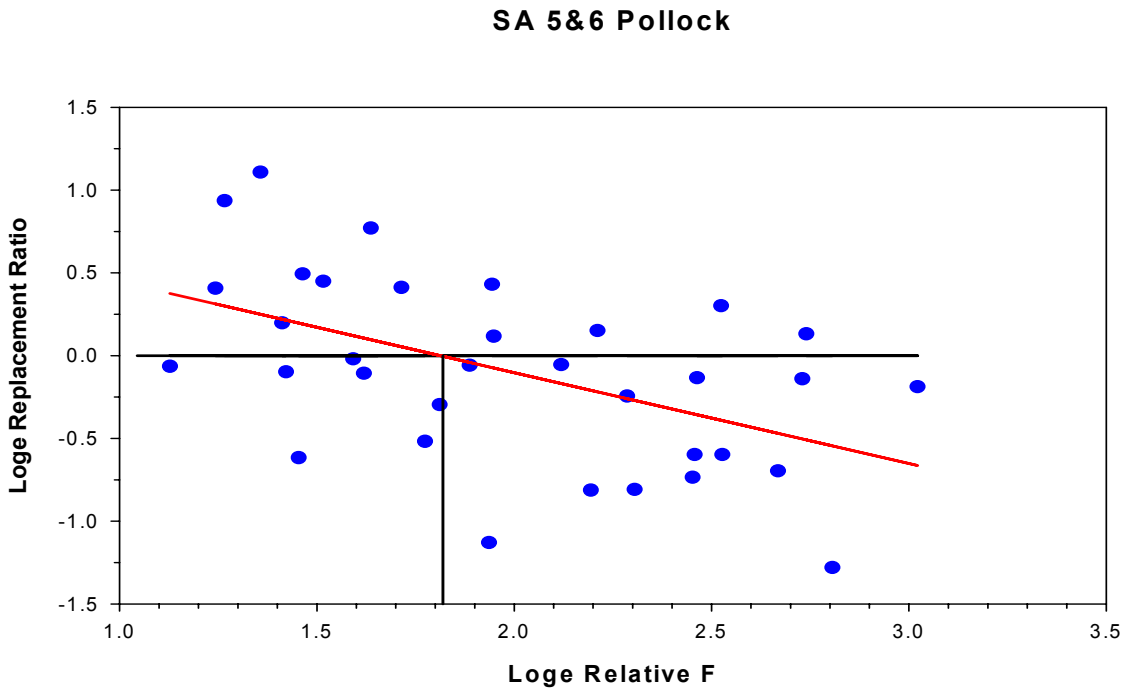

Figure L9. Relationship between the replacement ratio and relative F for pollock in Subareas 5 and 6, 1963-2001.

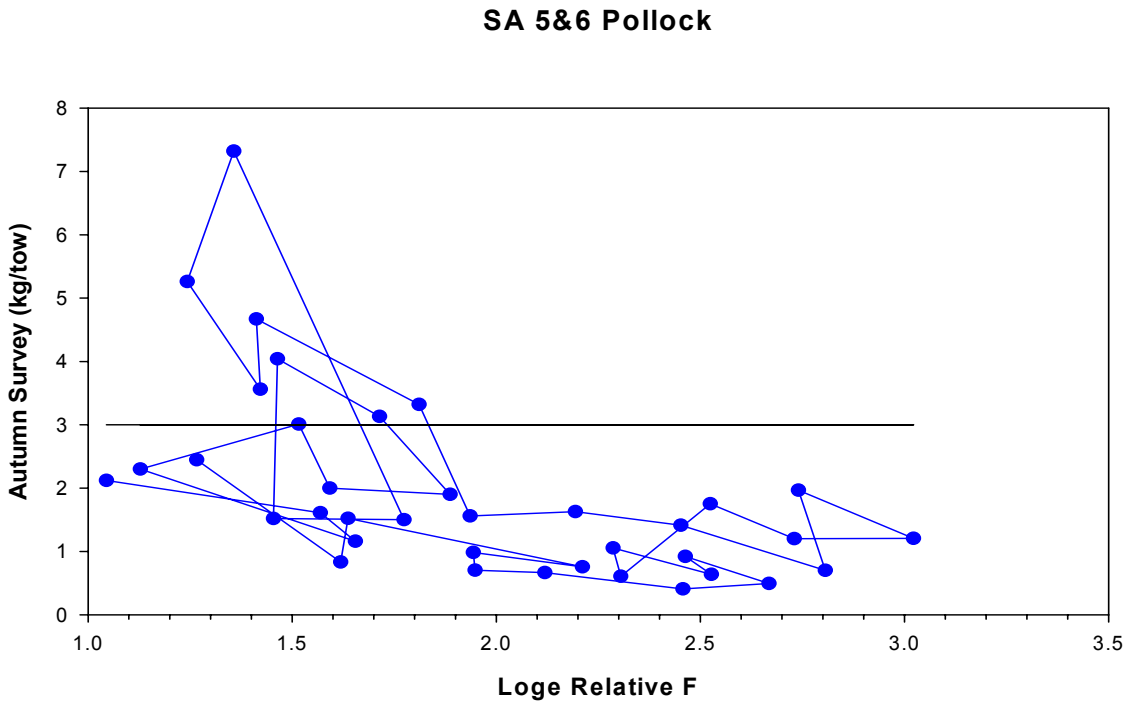

Figure L10. Relationship between the NEFSC autumn survey biomass index and relative F for pollock in Subareas 5 and 6, 1963-2001.

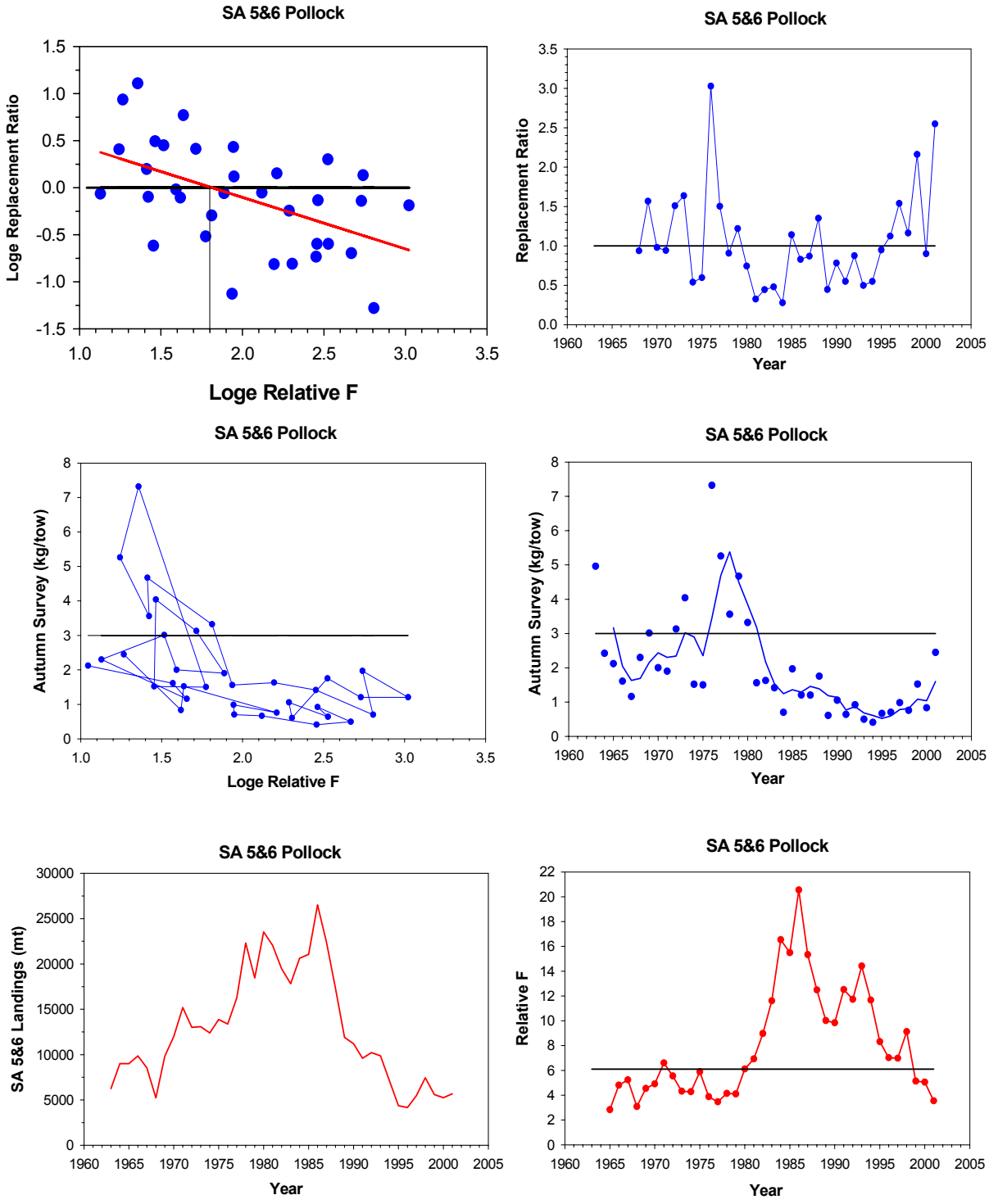

Figure L11. Six-panel plot illustrating relationships between landings, survey biomass indices, relative F, and replacement ratios for pollock in Subareas 5 and 6, 1963-2001.